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# IP Over WDM

The physical layer protocol for the U.S. long haul optical network is the Synchronous Optical Network (SONET) protocol, which was developed at a time when the majority of traffic over the telecommunications network was voice. SONET follows the traditional synchronous hierarchy – frames are 125 microseconds in length and are built up in integral multiples of OC-1 units (i.e., 51.84 Mbps). The design of SONET was reasonable from the perspective of telephony carriers. As the volume of data traffic (mainly Internet IP packets) is poised to exceed the volume of voice traffic, the data communications community (particularly IETF stakeholders, such as router vendors) has come to question whether SONET provides the optimal multiplexing technique to carry IP traffic. Their major concerns are in the following areas:

1. **Inflexibility in bandwidth granularity** – Each traffic source must use a fixed multiple of the OC-1 rate, for example, OC-3 (155Mbps), OC-12 (622Mbps), OC-48 (2.4Gbps), and OC-192 (9.9Gbps). Many data applications, including TCP/IP, demand bandwidth in units significantly different from OC-x rates, and the bandwidth demands of such applications may vary dynamically. A new multiplexing technique is required to allocate bandwidth in finer granularity and with greater adaptivity.
2. **High overhead** – The SONET format includes a minimum of 3% overhead for framing, status monitoring, and management. Despite this overhead, many of the intended functions are not used. Furthermore, additional overhead appears when IP packets go through the AAL-ATM protocol stack on their way to the SONET framing layer.

Several organizations are working toward alternatives to SONET. Two proposed schemes are being actively considered, namely "IP over fiber" and "IP over light wave". In addition, there are proposals at the IETF to use point-to-point protocol (PPP) as the new framing protocol to replace SONET. Also, the Optical Interworking Forum (OIF) is starting a new effort to develop a lightweight SONET substitute (so called Diet SONET). Many issues must be investigated and solved. How can a laser be used to transmit fixed or variable length IP packets into the fiber? What is the design for a new framing protocol? What are appropriate mechanisms for status monitoring and network management? When addressing these issues, industry may reinvent the wheel and end up with new mechanisms just as complicated as the existing SONET. NIST has a role to play here – we can conduct evaluations on the effectiveness of various proposals to provide industry with clear, accurate, unbiased information to make the “right” decisions.

With the advent of wavelength division multiplexing (WDM) technology that allows multiple wavelengths on a single fiber, the "IP over fiber" issue takes on a new dimension. End stations (traffic sources) and routers (traffic switches) have a choice of wavelengths on which to direct their traffic. In this WDM domain, attempts to address issues such as light path selection and network routing, support for various classes of service, and algorithms for network restorations, may lead to interesting issues, and ultimately to a new paradigm for data transmission.

The optical component technology of the future may allow full optical switching of IP packets. The Advanced Network Technologies Division and the High Performance Systems and Services Division have had preliminary discussions on the use of holographic technology for control of IP packet switching. Holographic packet switching appears to be an innovative idea worthy of further investigation.

In summary, NIST has an important role to play, and the timing is perfect for us to take on the job. We propose to work with the new Optical Interworking Forum to conduct performance evaluations of proposals submitted to that organization. We will establish a testbed to prototype proposals and to conduct feasibility studies. The testbed will also allow us to build competency for future research work on all-optical packet switching. The proposed work consists of the following tasks.

**Task 1**. Work with the OIF, and other relevant standards groups, on the development of new protocols for IP over WDM, including framing, management, light path selection, and routing protocols. Our main focus will be on the evaluation of alternative proposals using software simulators to be developed as needed.

Proposed Deliverable: simulation tools and contributions to OIF and standards groups.

**Task 2**. Develop a testbed to prototype competing IP over WDM algorithms and to study end system (workstation) performance and end-to-end performance.

Proposed Deliverables:

1. A PCI bus WDM network interface card for PCs. The card will consisting of a general purpose framing chip, and optical transmitter and receiver. The transmitter may utilize a tunable laser. If feasible, the card will also incorporate the NIST Multikron chip to facilitate measurements to be done in task 3.
2. A complete PC system with the above interface card and necessary device drivers on the Linux platform.

**Task 3**. Conduct performance evaluations of an IP over WDM system using the NIST Multikron board. The performance study will include comparisons of throughput and access delay under various configurations: IP -> AAL -> ATM -> SONET, IP -> SONET, IP -> new framing, IP -> new framing -> WDM.

Proposed Deliverable: Journal papers on experimental results.

**Task 4**. Expand the above PC to be a router and make a network of IP over WDM routers. Conduct experiments on potential new wavelength routing algorithms.

Proposed Deliverable: Contributions to standards groups on evaluation results.